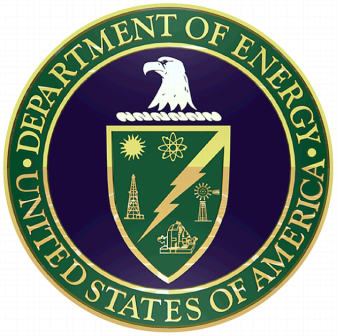
Carbonaceous Aerosol and Radiative Effects Study (CARES)

DOE ASP Field Campaign in 2010

Rahul Zaveri, Will Shaw, Dan Cziczo

Pacific Northwest National Laboratory

ASP Science Meeting
Santa Fe, February 26, 2009



Pacific Northwest
NATIONAL LABORATORY

Collaborators (Partial List)

PNNL
M.L. Alexander, J.C. Barnard, L.K. Berg, E.G. Chapman, R.C. Easter, J.D. Fast, W.I. Gustafson, J.M. Hubbe, A. Laskin, L.-Y. Leung, M. Pekour, J. Shilling, C. Song, X.-Y. Yu, and A. Zelenyuk

BNL
L.I. Kleinman, P.H. Daum, Y.-N. Lee, A. Sedlacek, G. Sennum, S.R. Springston, J. Wang

Other Institutions (listed in alphabetical order of the institution name)
Timothy B. Onasch, Scott C. Herndon, Douglas R. Worsnop, **Aerodyne Research, Inc**.
Eileen McCauley, Ajith Kaduwela, **California Air Resources Board**
W. Patrick Arnott, **Desert Research Institute/University of Nevada, Reno**
Manvendra Dubey, **Los Alamos National Laboratory**
Claudio Mazzoleni, **Michigan Technological University, Houghton**
Chris Hostetler, Rich Ferrare, **NASA Langley**
Sasha Madronich, **NCAR**
David Parrish, Tom Ryerson, **NOAA, Boulder**
Dean Atkinson, **Portland State University, Portland**
Jeff Gaffney and Nancy Marley, **University of Arkansas, Little Rock**
Kimberly A. Prather, **University of California, San Diego**
Tom Jobson, **Washington State University, Pullman**

Pacific Northwest
NATIONAL LABORATORY

CARES 2010 Objectives

- Evaluate and improve models of aerosol formation, aging, and their climate-relevant properties, with particular emphasis on:
  - Anthropogenic and biogenic SOA (interactions)
  - Evolution of aerosol mixing states (especially light absorbing carbon)
  - Optical and CCN activation properties (role of organics)
  - Biomass burning aerosols (target of opportunity)

Pacific Northwest
NATIONAL LABORATORY

Key Science Questions: SOA

- SVOC concentrations in a fresh urban emissions?
- Chemical composition (O/C, O/N ratios), volatility spectrum, and oligomeric fraction in observed OA?
- Enhanced biogenic SOA mass in the urban plume compared to outside of the urban plume?
- Correlations of modern and old carbon fractions with urban, biogenic, and biomass burning tracers?
- Vertical profiles of SOA?

Key Science Questions: Aerosol Mixing State

- Aerosol mixing state as a function of particle size in fresh and aged urban plumes?
- Morphology of aerosols as a function of mixing state?
- Relative roles of condensation and coagulation processes in shaping the aerosol composition and size distribution?
- Effect of aerosol mixing states on the ensemble aerosol optical properties, hygroscopicity, and CCN activity?
- Vertical profiles of aerosol mixing state?

Pacific Northwest
NATIONAL LABORATORY

Key Science Questions: Aerosol Optical Properties

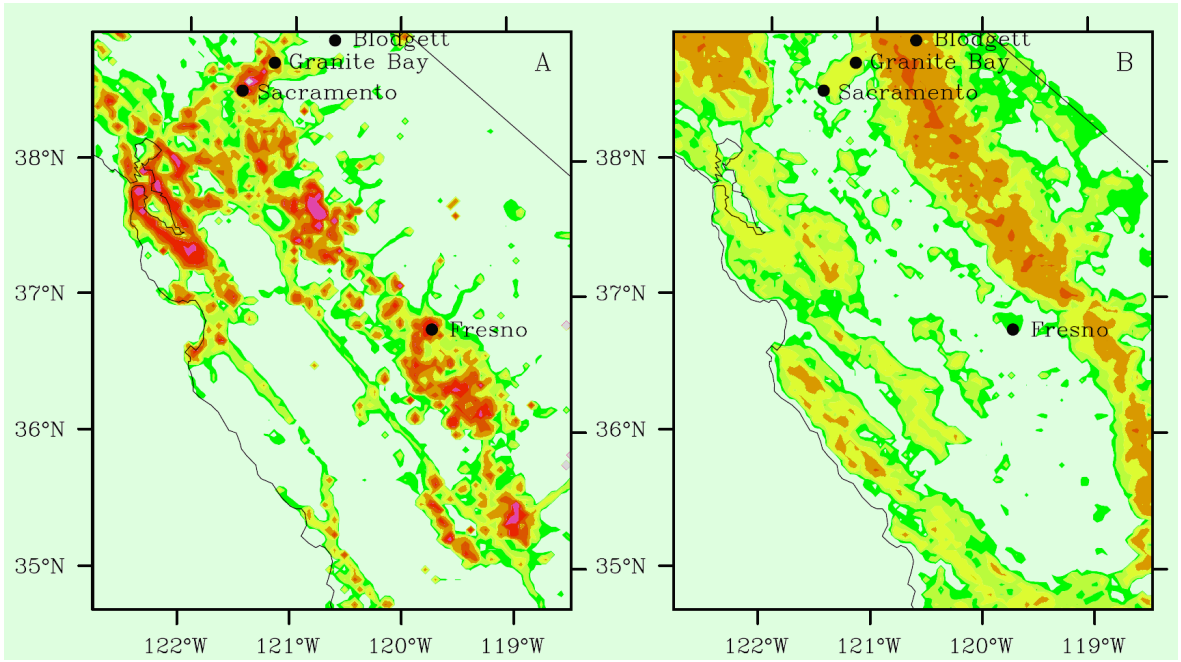
- Scattering and absorption as a function of aerosol mixing state?
- Enhanced near-UV and visible absorption in OA?
- Correlation of enhanced absorption to urban POA, biomass burning OA, and SOA?

Pacific Northwest
NATIONAL LABORATORY

Central Valley VOC Emissions

VOC Emissions [Steiner et al., 2007]

Anthropogenic VOC **Biogenic VOC**

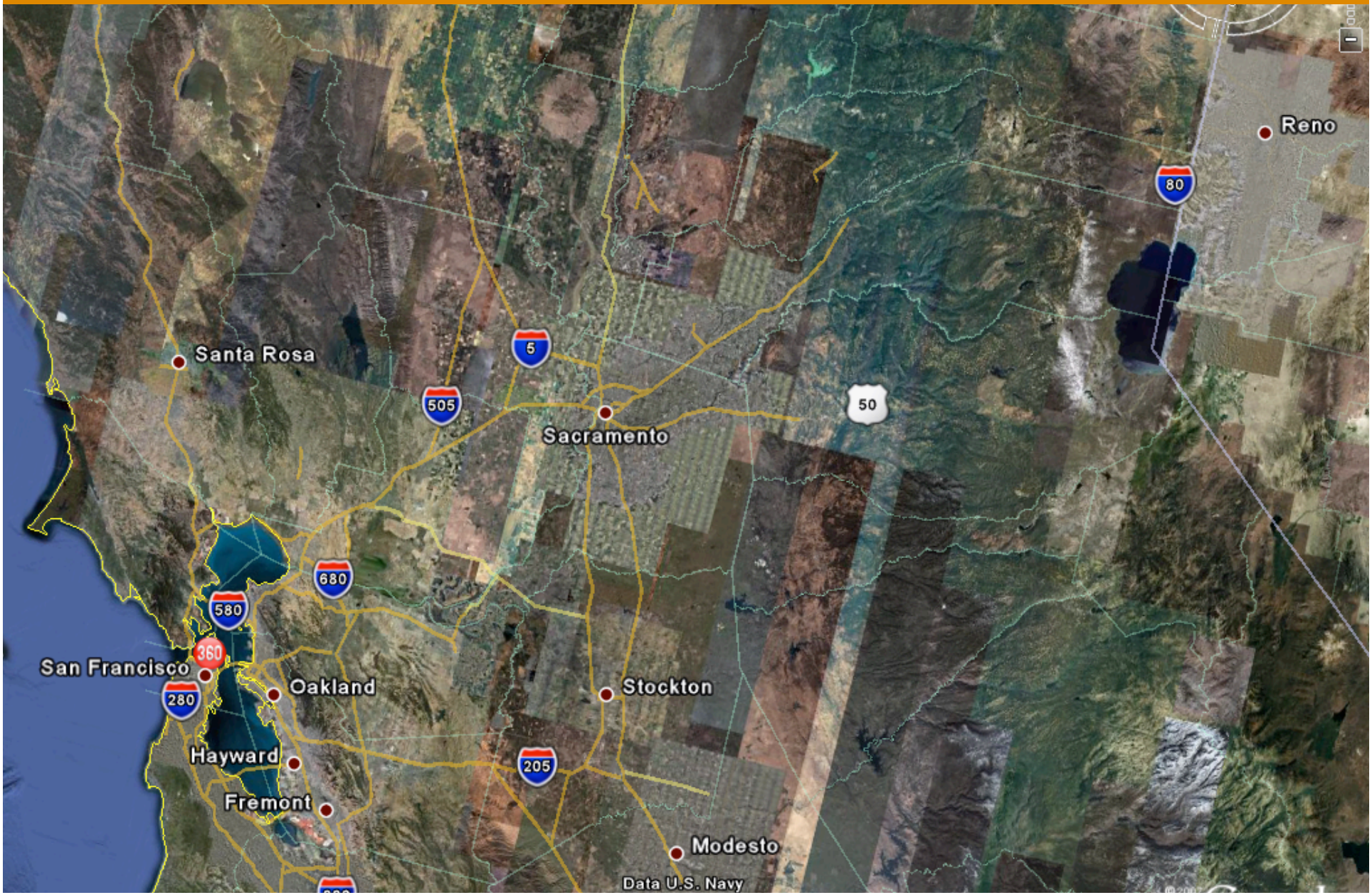


mol s^{-1}

0.002 0.005 0.01 0.02 0.05 0.1 0.2 0.5

Pacific Northwest
NATIONAL LABORATORY

Main Region of Interest for CARES

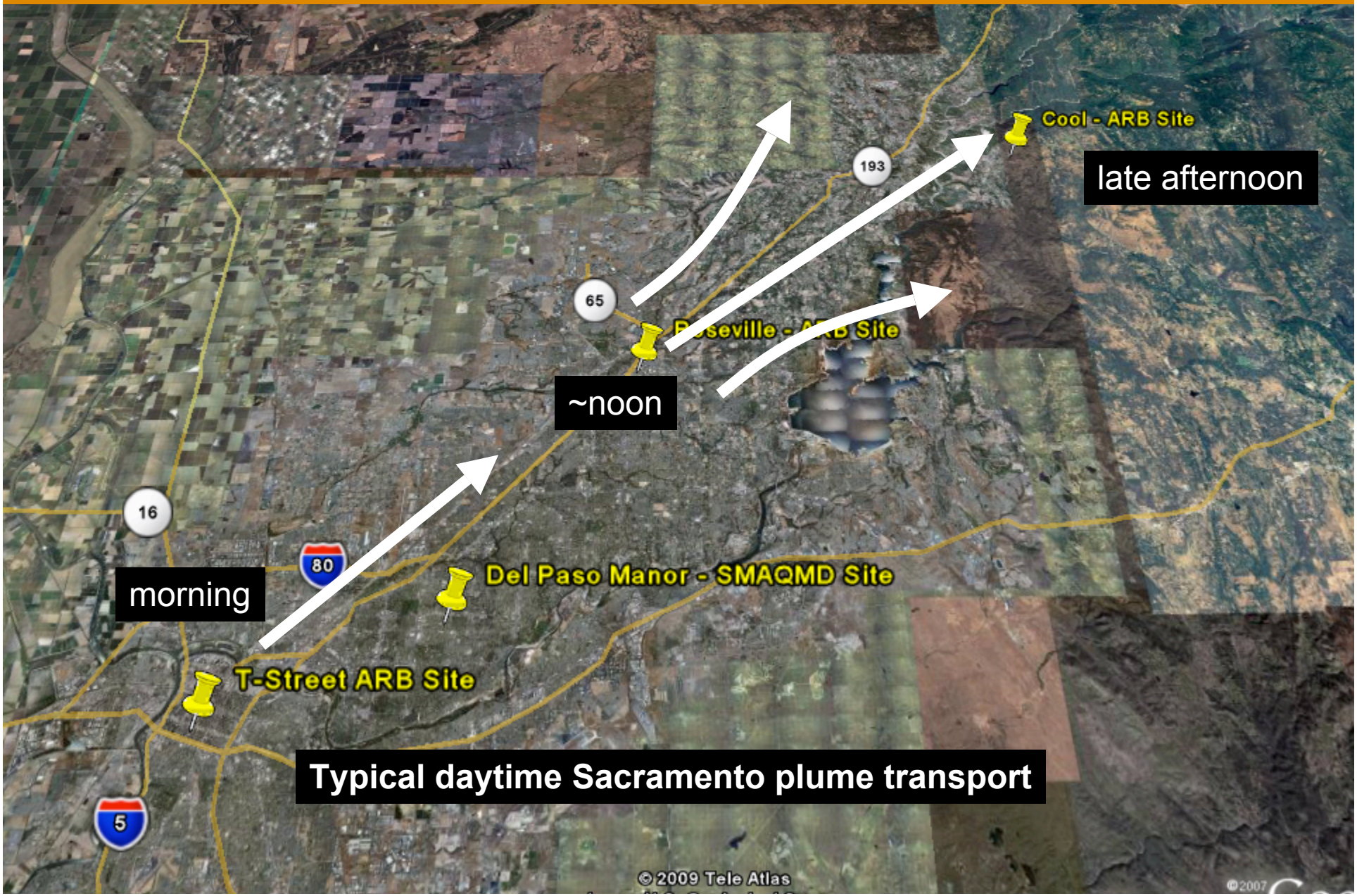


Scientific and Logistical Motivations

- Clear skies and highly regular wind patterns in summer
- Convenient to deploy ground sites and aircraft
- Detailed CARB emissions inventory (a big plus for modeling!)
- Several previous ground-based studies at this location provide a good foundation for an intensive ASP field project in 2010
  [e.g., Dillon et al., 2002; Murphy et al., 2006; Steiner et al., 2007; BEARPEX]
- Collaboration with NOAA, CARB, others. Opportunity to contrast CARES findings with CalNex/LA results.

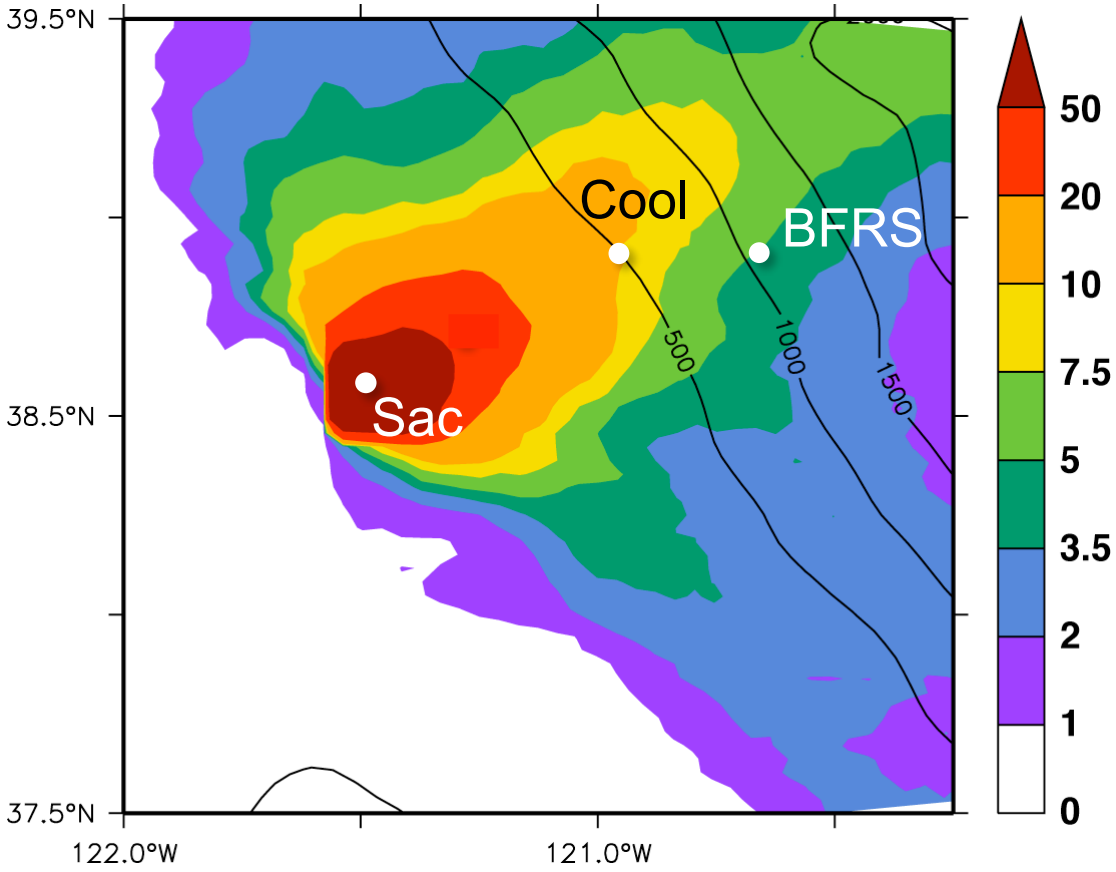
Pacific Northwest
NATIONAL LABORATORY

Focus on Sacramento Urban Plume

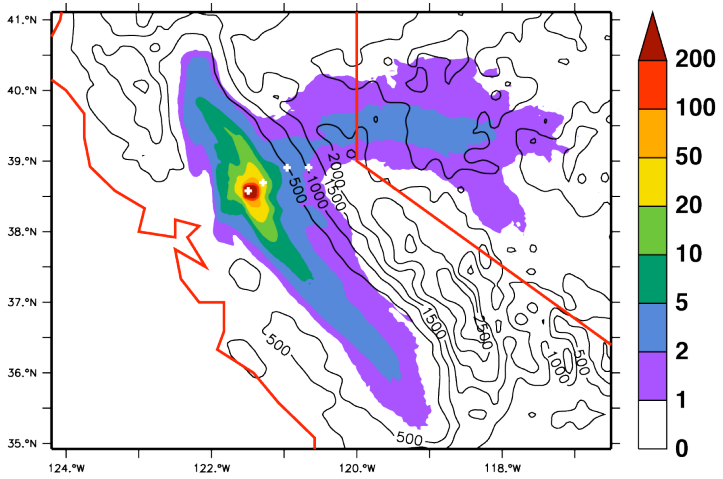


Pre-CARES Modeling: Footprint of Sac Emissions – June 2008

Good Transport Days, Noon-Midnight Hours



All Times and Days



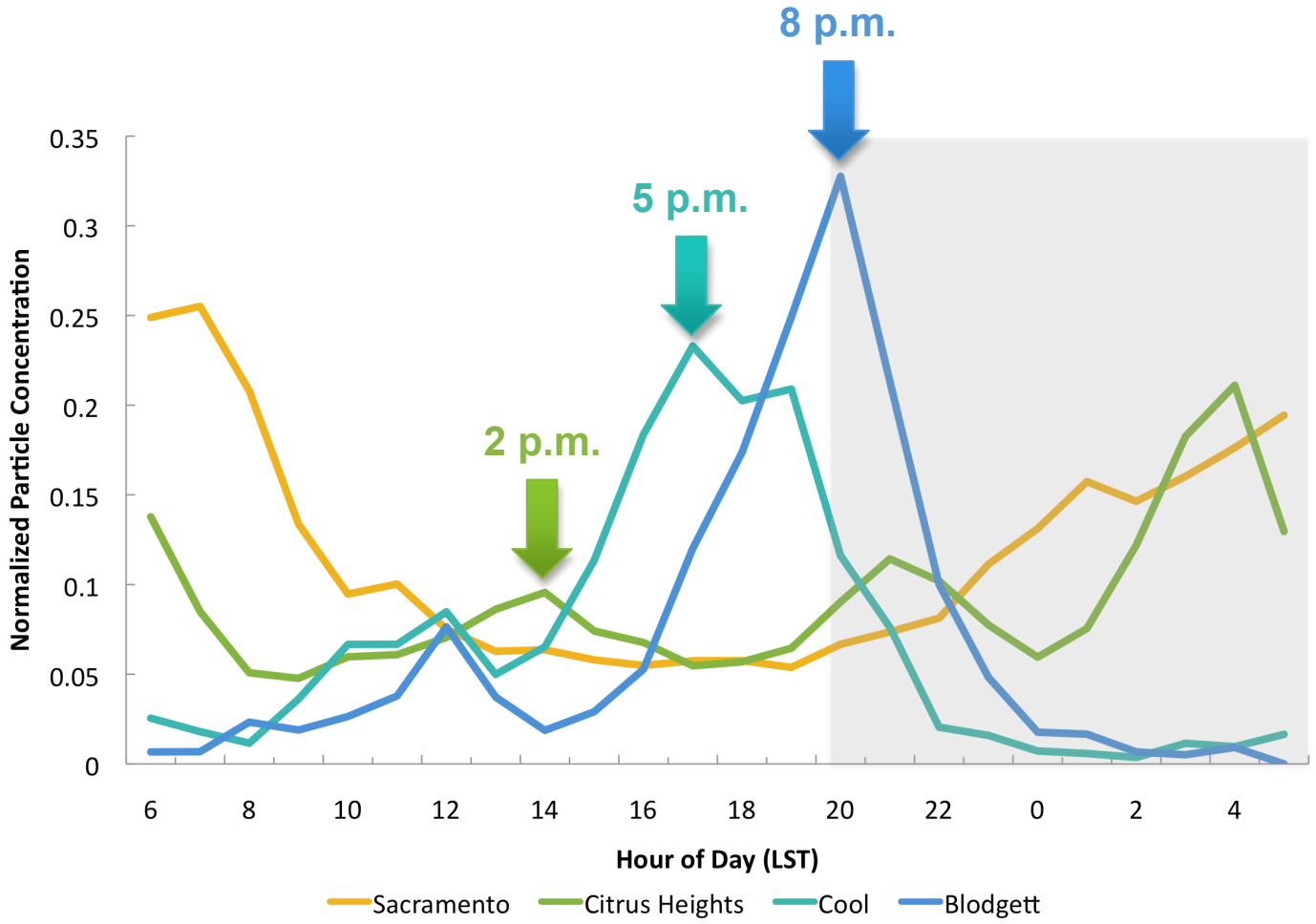
Sites from west to east:

- **Sacramento**
- **Cool**
- **Blodgett Forest**

Based on maximum transport time of 48 hours.

Analysis by W.I. Gustafson, Jr.

Composited Normalized Particle Concentrations

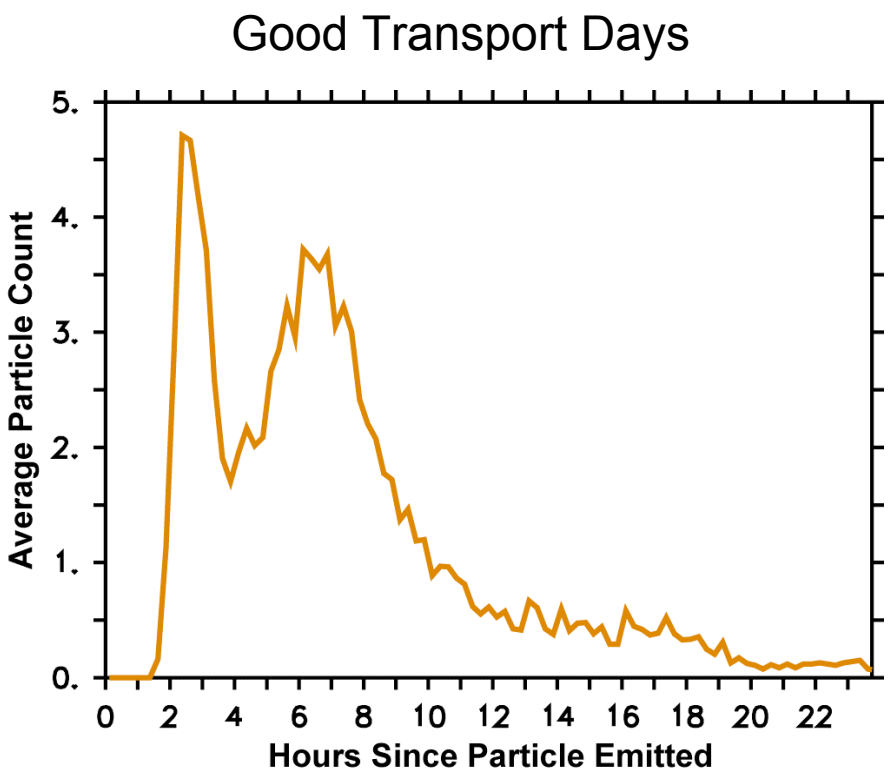


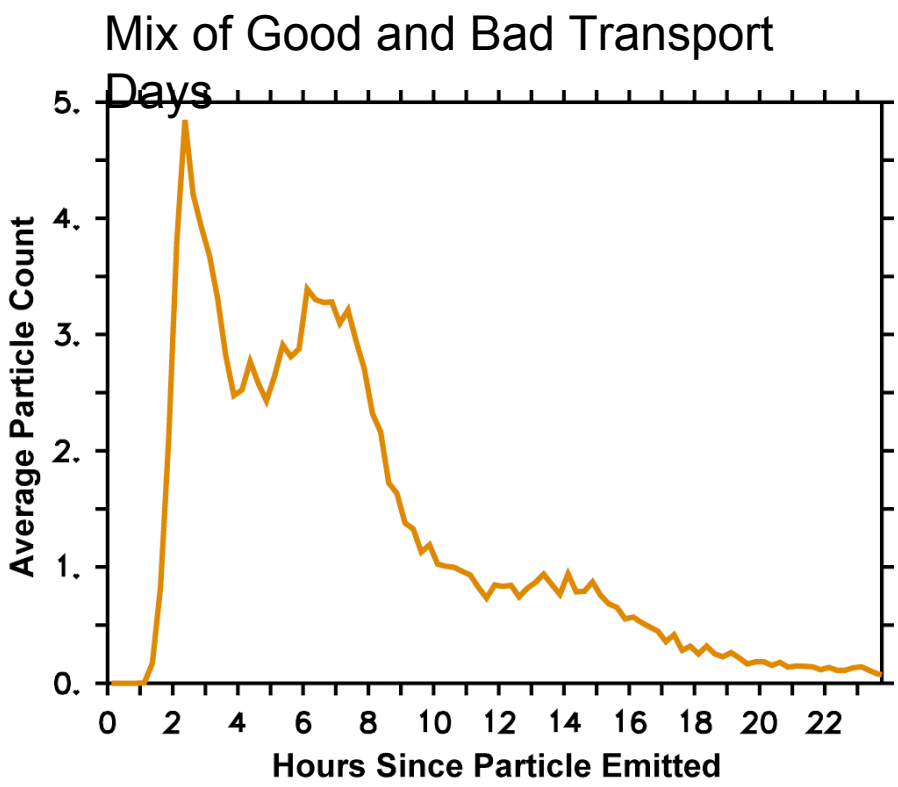
Composite includes 14 of 30 simulated days

Pacific Northwest
NATIONAL LABORATORY

Analysis by W.I. Gustafson, Jr.

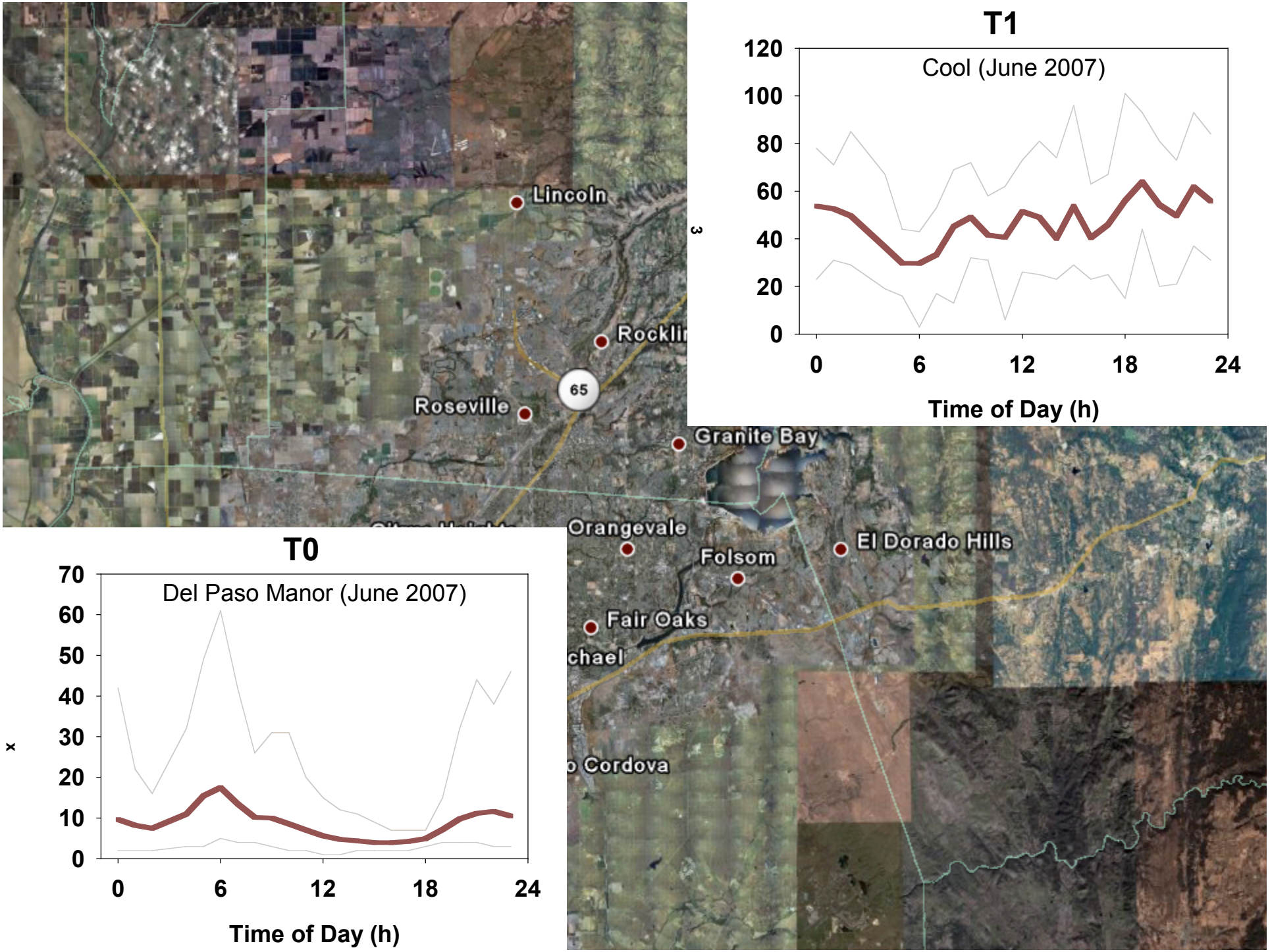
Particle Ages at Cool





Pacific Northwest
NATIONAL LABORATORY

Analysis by W.I. Gustafson, Jr.


Lincoln
Roseville
65
Granite Bay
Orangevale
Folsom
El Dorado Hills
Fair Oaks
chael
o Cordova

T1
Cool (June 2007)
120
100
80
60
40
20
0
0
6
12
18
24
Time of Day (h)

T0
Del Paso Manor (June 2007)
70
60
50
40
30
20
10
0
0
6
12
18
24
Time of Day (h)

CARES Logistics

- Where: Sacramento / Central Valley, California
- When: June 2010
- Measurements Platforms
  - DOE G-1 aircraft: Two 3-hour flights per day (total ~10-12 days)
  - NASA B-200 aircraft: Coordinated with the G-1
  - T0 Ground Site at Del Paso Manor
  - T1 Ground Site at Cool
  - Aerodyne Mobile Lab (pending ASP support)
- Aircraft Base
  - Mather Airport
  - Full-service FBO, 24-hour air traffic control, 11,300 feet runway.

T0 Site: Del Paso Manor High School

CARES Suite

Trace Gases		
PTR-MS & GC-MS	VOCs and SVOCs	Jobson/WSU
CO	VUV fluoroscence	Jobson/WSU
SO_2	research grade	Shilling/PNNL
O_3	research grade	Jobson/PNNL
NO, NO_2, NO_y	research grade	Jobson/PNNL
Aerosol Size/Composition		
SMPS	particle size distribution	Shilling/PNNL
C-ToF-AMS	non-refractory aerosol comp	Shilling/BNL
Sunset OC/EC	organic/elemental carbon mass	Shilling/PNNL
SPLAT-II	single-particle mixing state	Zelenyuk/PNNL
SP2	black carbon mass	?
TRAC, DRUM Samplers	microspectroscopic analyses	Laskin/EMSL, Gilles/LBNL
PILS Auto-sampler	high-res MS, WSOC, WSON	Laskin/EMSL
Radiocarbon Sampler	^{13}C and ^{14}C analysis	Gaffney/UA
Optical Properties		
PASS-3	absorption	Arnott/DRI
3-λ Nephelometer, 3-λ PSAP, CN	scattering, absorption	Shaw/PNNL
3-λ Cavity Ring Down	extinction, scattering	Atkinson/PSU
RSS, photolysis, MFRSR	radiation	Shaw/Barnard/PNNL
UV-MFRSR	radiation	?
Hygroscopic & CCN Properties		
HTDMA	aerosol hygroscopic properties	Zelenyuk/EMSL
CCN Counter	CCN activation	Shilling/PNNL
Meteorology		
Sodar	wind velocity vertical profile	Shaw/PNNL
Radiosonde	wind velocity, P, T, RH profiles	Shaw/PNNL

T1 Site: Northside School

CARES Suite

Trace Gases		
PTR-MS	VOCs	Newburn/PNNL
CO	VUV fluorescence	Pekour/PNNL ?
O_3	research grade	Song/PNNL
SO_2	research grade	Song/PNNL
NO_x, NO_y	research grade	Pekour/PNNL ?
Aerosol Size/Composition		
SMPS	particle size distribution	Song/PNNL
HR-ToF-AMS	non-refractory aerosol comp.	Song/PNNL
Sunset OC/EC	organic/elemental carbon mass	Song/PNNL
ATOFMS	mixing state & optical props.	Prather/UCSD
SP2	black carbon mass	?
TRAC, DRUM Samplers	microspectroscopic analyses	Laskin/EMSL, Gilles/LBNL
PILS Auto-sampler	high-res MS, WSOC, WSON	Laskin/EMSL
Radiocarbon Sampler	^{13}C and ^{14}C analysis	Gaffney/UA
Optical Properties		
PASS-3	absorption	Arnott/DRI
3-λ Nephelometer, 3-λ PSAP, CN	scattering, absorption	Pekour/PNNL
3-λ Cavity Ring Down	extinction, scattering	Atkinson/PSU
RSS, photolysis, MFRSR	radiation	Barnard/Pekour/PNNL
UV-MFRSR	radiation	Gaffney/UA
Hygroscopic & CCN Properties		
HDTMA	aerosol hygroscopic properties	Cziczo/PNNL
CCN Counter	CCN activation	Cziczo/PNNL
Meteorology		
Sodar	wind velocity vertical profile	?
Radiosonde	wind velocity, P, T, RH profiles	?

Aerodyne Mobile Laboratory (pending ASP support)

Instrument Suite

- Aerosol Mass Spectrometer (AMS) with the black carbon detection module (SP2)
- Scanning Mobility Particle Sizer (SMPS)
- Multi-angle absorption photometer (MAAP)
- CAPS-extinction and SSA instruments
- Gas Chromatogram, originally based on TO-14 method targeting aromatics and semi-volatiles
- QC-TILDAS – HCHO/HCOOH and NH_3
- PTR-MS
- NO, NO_2 (direct TILDAS), NO_y, O_3, CO, CO_2
- Eppley uv, atmospheric temperature, pressure, wind direction, wind speed, relative humidity

DOE G-1 Aircraft Measurements

- **Platform**
  - Gulfstream 159, N701BN
  - Nominal flight altitude: 25 kft (7.6 km)
  - Useful load: ~4000 lb
  - Sampling speed: 195 knots (100 m/s)
  - Mission duration: ~4 hours
  - Science flight hours: ~70 h
  - Based in Sacramento (Mather Field)

G-1 Administered by PNNL's Airborne Facility and Programs Office

- **Basic Instruments**
  - total temperature
  - static pressure
  - gust-probe differential pressures
  - platform position/velocity/attitude
    - static temperature
    - potential temperature
    - winds
  - dew-point temperature
  - aerosol spectrum, 0.1-3 um (PCASP)
  - particle count, >7nm (CPC)
  - particle count, >3nm (uCPC)
  - particle light scattering (nephelometer)
  - particle absorption (PSAP)
  - isokinetic aerosol inlet

Pacific Northwest
NATIONAL LABORATORY

DOE G-1 CARES Suite

Trace Gases		
PTR-MS	VOCs	Alexander/EMSL
CO	VUV fluorescence	Springston/BNL
O_3	research grade	Springston/BNL
SO_2	research grade	Springston/BNL
NO_x, NO_2, total NO_y	research grade	Springston/BNL
Aerosol Size/Composition		
TSEMS	particle size distribution	Wang/BNL
FIMS	particle size distribution	Wang/BNL
C-ToF-AMS (LS module)	non-refractory aerosol comp.	Alexander/EMSL ?
SP2	black carbon mass	?
ATOFMS	mixing state & optical props.	Prather/UCSD
TRAC, DRUM Samplers	microspectroscopic analyses	Laskin/EMSL, Gilles/LBNL
PILS Auto-sampler	high-res MS, WSOC, WSON	Laskin/EMSL
Optical Properties		
PASS-3	absorption	Dubey/LANL
PTI	absorption	Sedlacek/BNL
3-λ Nephelometer	scattering	Hubbe/PNNL
PSAP	absorption	Hubbe/PNNL
Radiation	down/up spectrally resolved	Hubbe/PNNL

Some Missing Measurements

- f(RH)
- Aerosol volatility – thermal denuder
- Black carbon – SP2
- UV-MFRSR

Pacific Northwest
NATIONAL LABORATORY

NASA B-200 Deployment for CARES 2010

- **Platform**
  - NASA Langley King Air B-200
  - Nominal flight altitude: 28 kft (~ 9 km)
  - Aircraft speed: 200-220 knots
  - Aircraft duration: 4-5 hours
  - Science flight hours: ~70 h
  - Based in Sacramento with DOE G-1

- **Instruments**
  - High Spectral Resolution Lidar — Ferrare/Hostetler NASA Langley
  - Digital Camera — Ferrare/Hostetler NASA Langley
  - Research Scanning Polarimeter — (possible) Cairns NASA/GISS)

- **Objectives**
  - Support DOE G-1 operations (reconnaissance and real-time direction)
  - Characterize the vertical and horizontal distribution of aerosols and aerosol optical properties
  - Provide the vertical context for G-1 and ground in situ measurements
  - Infer aerosol type and apportion optical depth by type
  - Investigation of new active + passive (lidar + radiometer) aerosol retrieval techniques
  - Characterize the PBL height and distribution of aerosols within and above PBL
  - Assess aerosol model transport simulations
  - CALIPSO/CALIOP & GLORY/APS Validation

Pacific Northwest
NATIONAL LABORATORY

NASA Langley Airborne High Spectral Resolution Lidar (HSRL)

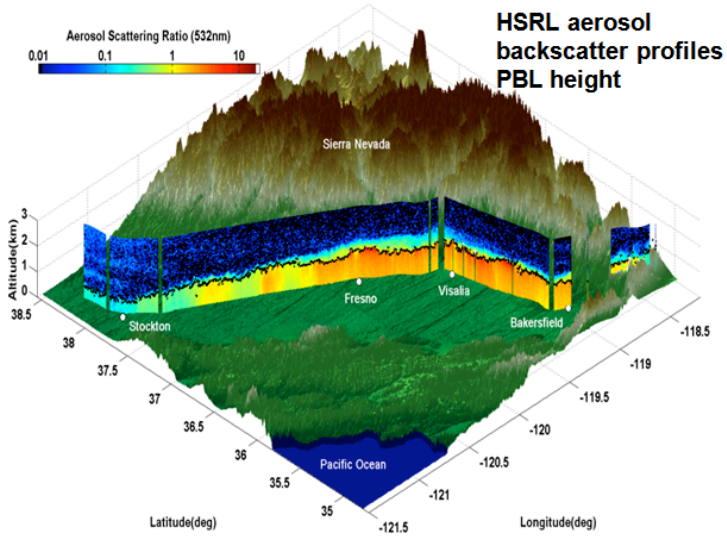
HSRL Technique (Hair et al., AO, 2008):

- Relies on spectral separation of aerosol and molecular backscatter in lidar receiver
- Independently measures aerosol backscatter, extinction, and optical thickness
- Internally calibrated
- Provides intensive aerosol parameter to help determine aerosol type

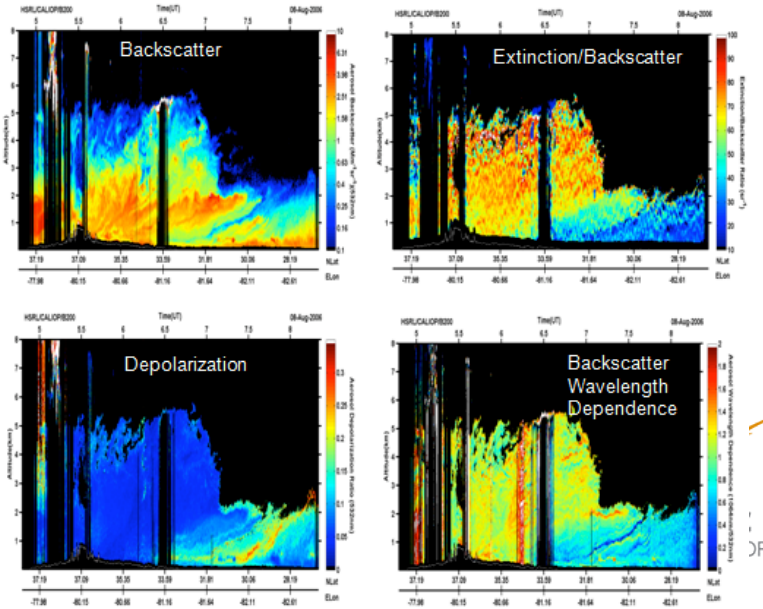
HSRL Aerosol Data Products:

- Scattering ratio (532 nm)
- Backscatter coefficient (532, 1064 nm)
- Extinction Coefficient (532 nm)
- Backscatter Wavelength Dependence (532/1064 nm)
- Extinction/Backscatter Ratio ("lidar ratio") (532 nm)
- Depolarization (532, 1064 nm)

February 15, 2007 Flight over San Joaquin Valley



August 8, 2006 CALIPSO Validation Flight



(Tentative) NASA GISS Research Scanning Polarimeter (RSP): Possible Deployment for CARES

Measurements

- Total and linearly polarized reflectance in nine spectral channels
- 152 viewing angle samples over 120 deg angular range

Derived parameters

- Aerosols
  - optical depth
  - location and width of both modes of bimodal size distribution
  - refractive index
  - estimates of size and amount of accumulation mode aerosols above clouds
- Clouds
  - optical depth
  - effective radius, variance
  - liquid water path
  - cloud drop number concentration

Pacific Northwest
NATIONAL LABORATORY

Pre-campaign Activities

- **Available data and information**
  - Attend the BEARPEX data workshop
  - Obtain and examine ARCTAS data from Hanwant Singh
- **CARB Emissions inventories**
  - Obtain anthropogenic/urban emissions of trace gases
  - Work with CARB/SMAQMD to develop a detailed biogenic VOC inventory
  - Develop size-resolved primary aerosol emissions
- **Pre-campaign modeling**
  - Box-model simulations
  - 3-D WRF-Chem simulations
- **Prepare flight plan playbook for G-1 and B-200**
  - Sac-Cool Corridor – upwind, over, downwind
  - Along the Central Valley and over other CalNex sites
  - Coordinated with NOAA WP-3

During Campaign: Flight Plans & Collaborations

- Forecast products during the campaign
  - WRF, WRF-Chem products for flight planning and Aerodyne Van deployment
- Near real-time data to be made available.
- Coordinated flights of **G-1** and **B-200** upwind, within, and downwind of Sacramento.
- Coordinated **G-1** and **B-200** flights along the Central Valley and over other CalNex ground sites, depending on the meteorological situation.
- Coordinated flights of **G-1**, **B-200**, and **WP-3** as opportunity arises
  - Wing-tip intercomparisons
  - Race track pattern

Want to Contribute to CARES 2010?

- Contribute additional measurements to ground sites
- Participate in pre-campaign and post-campaign modeling activities
- Provide logistical support during the campaign
- Got ideas to make it better?

Contact:

Rahul Zaveri – rahul.zaveri@pnl.gov

Will Shaw – will.shaw@pnl.gov

Dan Cziczo – dan.cziczo@pnl.gov

Pacific Northwest
NATIONAL LABORATORY